SUBSTITUTE SPECIFICATION

TITLE: DISC DRIVE FOR AN OPTICAL SCANNING DEVICE

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DISC DRIVE FOR AN OPTICAL SCANNING DEVICE

BACKGROUND OF THE INVENTION

Field Of The Invention

The present invention generally relates to optical scanning devices for storing information onto a disc-shaped storage medium or reading information from such disc-shaped storage medium, where the disc is rotated and a write/read head is moved radially with respect to the rotating disc. More particularly, the invention relates to an optical disc drive comprising rotating means, defining a rotating axis for an optical disc, and optical scanning means, for scanning said optical disc with a light beam.

The present invention is applicable in the case of optical or magneto-optical disc systems. Hereinafter, the wording "optical disc system" will be used, but it is to be understood that this wording is intended to also cover magneto-optical disc systems.

Description Of The Related Art

It is commonly known that an optical storage disc comprises at least one track of storage space where information (such as images, data, music,…) may be stored. Optical storage discs may be of a read-only type, where information is recorded during manufacture and can only be read by a user, or of a writable type, where information may be stored by a user. For writing

information in the storage space of the optical storage disc or for reading information from the disc, an optical disc drive comprises, on the one hand, rotating means for receiving and rotating the optical disc and, on the other hand, optical means for generating an optical beam, typically a laser beam, and scanning the storage track with said laser beam. The rotating means is, for example, a motor, which drives a hub engaging a central portion of the optical disc. For optically scanning the rotating disc, the optical disc drive comprises, for instance, at least a light beam generator device (typically a laser diode), an objective lens, for focusing the light beam in a focal spot on the information layer of the disc, and an optical detector, for receiving the light reflected from the disc and generating an electrical detector output signal. Since the technology of optical discs, i.e., the way in which information can be stored in an optical disc and the way in which optical data can be read from an optical disc are commonly known, it is not necessary here to describe this technology in more detail.

In an ideal case, the information layer of the disc is assumed to be perpendicular to the optical axis of the apparatus, so that the returning beam, i.e., the light reflected from the disc, is co-axial and counter propagates to the incoming light. In the case where the disc has a warped surface, the propagation axis of the reflected light is no longer co-axial to the axis of the incoming light, and a tilt effect, consisting in a deviation of the

returning beam from the co-axial propagation of the ideal case, is observed. Such a disc-tilt is known to degrade the performance of optical disc-drives and has to be detected and compensated. Nevertheless, since the incoming light is focused to a tiny spot on the information layer of the disc, this deviation from co-axial propagation is very small and a tilt detector based on this principle of detection of said deviation is very difficult to implement.

It has then been proposed to amplify the deviation of the returning beam, for instance by adding aberrations to the incoming beam and therefore causing the spot size on the information layer to increase. For instance, when the disc is accessed with infra-red light (wavelength = about 790 nm), the larger amount of spherical aberration (said aberration being due to the fact that, in a radiation beam, the rays in the central part of the beam and the rays of the periphery of the beam have different focal points when they are focused on the disc) causes the spot size on the information layer of the disc to increase compared to the situation where the disc is accessed with red light (wavelength = about 660 nm). An example of such a situation is described in Japanese Patent JP2000076679, where disc-tilt is measured from the position of a spot with a light source having a wavelength different from the wavelength used for reading out the information on the disc. It turns out, however, that, when such a method is applied, the size of the spot on the optical detector is now too large compared to

the size of the standard four-quadrant detector conventionally used in optical disc drive apparatuses: no significant difference in the signals from the quadrants of the detector can be measured, and hence no tilt error signal can be derived.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide an optical disc drive avoiding this drawback.

To this end, the invention relates to an optical disc drive as defined in the introductory paragraph of the description and in which the optical scanning means itself comprises at least:

[[-]] a first light source, for producing said first light beam;

[[-]] focusing means, applied to said light beam and provided between said first light source and a focusing point on an information layer on said first disc having a first cover layer;

[[-]] an optical detector provided for receiving a first backward beam reflected from said information layer of said first disc;

[[-]] a second light source for producing a second light beam also transmitted to said focusing means and for measuring tilt from the position, on said optical detector, of a second spot corresponding to a second backward beam obtained after reflection of said second light beam on said information layer of said first disc;

said optical disc drive further comprising, between said focusing point and said optical detector, a diffractive structure provided with diffracting elements for substantially refocusing the returning second beam onto the detector.

This structure allows to generate, on the detector, a spot small enough in order to be able to measure significant differences between the signals of the detector and, therefore, to derive a noticeable tilt error signal.

Preferably, the diffractive structure is attached to one surface of a servo-lens positioned just before the optical detector. However, it may alternatively be attached to one surface of an objective lens used as focusing means, or to a separate plate.

In an advantageous implementation, the diffractive structure consists of a series of ring-shaped prisms, but it can also be approximated by a step-wise structure.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example only, in a more detailed manner and with reference to the accompanying drawings, in which:

[[-]] Fig. 1 illustrates an example of optical disc drive suitable for storing information on or reading information from an optical disc;

[[-]] Fig. 2 shows an example of optical scanning device;

[[-]] Figs. 3 and 4 show two views (from the top and in cross section, respectively) of a first implementation of the diffractive structure according to the invention;

[[-]] Fig. 5 shows a phase-step structure that is an approximation of the prism structure illustrated in the cross section of Fig. 4;

[[-]] Figs. 6 and 7 illustrate the size and localization of the spot, respectively, without and with the diffractive structure according to the invention;

[[-]] Fig. 8 is a graph showing a simulated normalized radial-tilt error-signal obtained in the case of the implementation of Figs. 3 and 4;

[[-]] Fig. 9 is a graph showing a similar normalized radial-tilt error-signal obtained in the case of the implementation of Fig. 5;

[[-]] Fig. 10 shows how the light passes through the objective lens and is focused on the information layer, and Fig.11 is a magnified view of the region around said information layer; and

Fig. 12A shows the diffractive structure attached to a servo-lens, and Fig. 12B shows the diffractive structure attached to an objective lens.

DETAILED DESCRIPTION OF THE INVENTION

An example of an optical disc drive, suitable for storing information on or reading information from a first type optical disc 1, is schematically illustrated in Fig.1. The disc drive comprises an apparatus frame 2 and, for rotating the first type disc 1, a motor 3 fixed to the frame 2 and defining a rotation axis 4. For receiving and holding the first type disc 1, the disc drive may comprise a turntable or clamping hub 5, which is mounted on the axle 6 of the motor 3. The disc drive also comprises a sledge 7, which is displaceably guided in the radial direction of the disc 1, i.e., in a direction substantially perpendicular to the rotation axis 4, by guiding means not shown for the sake of clarity. A radial sledge actuator 8 is provided for regulating the radial position of the sledge 7 with respect to the apparatus frame 2.

The disc drive further comprises a platform 9, which is displaceable in the radial direction of the disc 1 with respect to the sledge 7, and which is displaceably mounted with respect to the sledge 7 by mounting means not shown for the sake of clarity. A radial platform actuator 10 is provided for radially displacing the platform 9 with respect to the sledge 7. Radial sledge actuators and radial platform actuators are known per se, and as the design and operation of such radial platform actuator are not the subject of the present invention, it is not necessary here to discuss them in great detail.

The disc drive further comprises, for scanning the tracks (not shown) of the first type disc 1 by means of an optical beam,

an optical device 20 which is described later. It also comprises a pivot platform actuator 11, arranged for pivoting the platform 9 with respect to the sledge 7 (such pivot platform actuators are known per se and therefore not discussed in great detail), and a control unit 12 having the following outputs: a first output 12a connected to a control input of the motor 3, a second output 12b coupled to a control input of the radial sledge actuator 8, a third output 12c coupled to a control input of the radial platform actuator 10, a fourth output 12d coupled to a control input of an axial platform actuator 13, and a fifth output 12e coupled to a control input of the pivot platform actuator 11. The control unit 12 is designed to generate at said outputs 12a to 12e control signals S_{CM}, S_{CS}, S_{Cpr}, S_{Cpa} and S_{CPp}, respectively, for controlling the motor 3, the sledge actuator 8, the radial platform actuator 10, the axial platform actuator 13 and the pivot platform actuator 11. The control unit 12 has also a read signal input 12f for receiving a read signal S_R from an optical detector described in the following paragraphs.

The optical scanning device 20 will now be described. According to a preferred embodiment of the invention illustrated in Fig. 2, the optical scanning device comprises light beam generation means 21 (first light beam), typically a laser, which may be mounted with respect to the frame 2 or the sledge 7. This laser 21 produces a diverging radiation beam 22 of a given first wavelength (in this example 660 nm), and the linearly polarized light flux

thus emitted is reflected by a semi-transparent mirror 23 and transmitted through a polarized beam-splitter 24 towards a mirror 25 and a lens system. This lens system includes a collimator lens 26, that changes the diverging radiation beam 22 to a collimated radiation beam 28, and an objective lens 27, that transforms said collimated beam into a converging beam 29 which comes to a focus 30 on the information layer of the first type disc.

After its reflection on said information layer, the converging beam 29 forms a reflected beam which returns on the same optical path. This backward radiation is further transmitted through the polarized beam-splitter 24 and passes through a servo-lens 40 which transforms said returning beam into a converging beam 41 falling on an optical detector, such as a servo-detector 42. The semi-transparent mirror 23 is constructed with optical elements that allow to separate the emitted beam and the returning one and to supply the latter to the optical elements (40, 42) that follow said mirror.

In order to obtain a measure of the amount of radial and tangential tilt of the first type disc 1, a second light source 51, typically a laser with a second wavelength different from said first wavelength (in this example 780 nm), is temporarily switched on for producing a second light beam. By definition, the two wavelengths are considered as different when the absolute difference between them is more than 10 nm. The polarized light emitted by said light source 51 is reflected by the polarized beam-

splitter 24 and the mirror 25, and then passed through the collimator lens 26 and focused by the objective lens 27. A second backward beam obtained after reflection of said second beam on the information layer is then received by the servo-detector 42. Since the wavelength of the second light beam is different from that of said first light beam, the spot on the information layer of the first type disc is now aberrated. As a result the size of the spot on the detector of this second beam becomes larger than the size of the detector.

According to the invention, it is proposed, in order to overcome the problem of the size of the spot on the servo-detector, to attach to one surface of one of the lenses located on the path of the backward beam or on a separate plate, between the focusing point on the information layer and the servo-detector, a diffractive structure implemented as described hereinunder. By doing so, the size of the spot on the servo-detector is reduced when accessing the first type disc with the light emitted by the second light source.

An example of this diffractive structure is shown in Figs 3 and 4. For the second light beam produced by radiation source 51, the diffractive structure should diffract the light beam substantially in one particular diffraction order. In this example, the case where the light is diffracted into the first diffraction order is considered. This can be achieved by a diffractive structure 100, shown mounted on a plate 102, which is of a blazed

grating type and consists of a series of ring-shaped prisms 101, as seen from the top (in Fig.3) and in cross-section along the radius (in Fig.4). In the cross-section of Fig.4, the numbers indicate the radial position of each of the diffracting elements, in millimeters. The height h_2 of the prisms is given by:

$$h_2 = \bullet_2/(n_2-1) \qquad (1)$$

where $\bullet_2$ is the wavelength of the light emitted by the second light source 51 and n_2 is the refractive index of the prism material at the wavelength $\bullet_2$. As shown in Figs 3 and 4, the central region of the diffractive structure (until a radius of 0.154 mm) does not contain any diffracting element. The size of this region is chosen so that when accessing a second type disc having a second cover layer with light from the second light source 51, the reflected light passes the structure 100 unaltered, while, when accessing the first type disc having the first cover layer with light from said second light source, a substantial amount of the rays of the divergent returning beam that fall outside the detector 42 are re-focused onto said detector. The following table 1 gives typical values for the radius (in millimeters) of the successive rings constituting the diffracting structure, together with the pitch, i.e., the distance between two successive rings, in micrometers:

Table 1

Ring number	Radius (mm)	Pitch (µm)

1	0.154	0.0
2	0.217	63.2
3	0.265	48.0
4	0.306	40.1
5	0.340	35.0
6	0.372	31.3
7	0.400	28.6
8	0.427	26.4
9	0.451	23.0
10	0.474	21.7
11	0.496	20.6
12	0.517	19.6

An important feature of the diffractive structure is that it should not influence the returning light of said first light beam when this light is used to access said first type disc. A blazed grating however also diffracts the first light beam significantly into the first diffraction order. In order to prevent this, instead of a blazed grating a binary grating must be used. In a binary grating, each blaze is approximated by a step-wise structure (see Fig. 5). International Patent Application No. WO02/21522 describes how to design such binary gratings diffracting a substantial part of the second light beam to the first diffraction order while not influencing the first light beam. The methods explained in this patent application are therefore included

by reference. This result may be obtained with the proposed step-wise structure of Fig. 5 where the blazed grating is approximates with four steps (105, 106, 107 and 108). It can be shown that with this structure, the light emitted by the first light source is unaltered by the grating, because the step heights have been chosen as multiples of h_1, each h_1 step leading to a phase shift of 2• when using light from the first light source (the phase shift for light emitted by the second light source is generally not 2•). The step height h_1 is given by:

$$h_1 = \bullet_1/(n_1-1) \qquad (2)$$

where $\bullet_1$ is the wavelength of the light emitted by the first light source and n_1 is the refractive index of the grating material at the wavelength $\bullet_1$. Here, for exemplary purposes, the refractive index of the grating material for both $\bullet_1$ and $\bullet_2$ is assumed to be 1.65. For the situation shown in Fig. 5, the height of step 105 is 1 x h_1, the height of step 106 is 2 x h_1, the height of step 107 is 4 x h_1 and the height of step 108 is 5 x h_1. The diffraction efficiency of the shown step structure is approximately 75 per cent.

The diffractive structure used, according to the invention, to reduce the size of the spot from the second light source on the servo-detector is either attached to the servo-lens or to the objective lens or on a separate plate. In the first case, as shown in Fig. 12A, the diffractive structure 100 (such as illustrated in Fig. 5) is attached to the front surface of the

servo-lens 40, and Figs 6 and 7 show respectively the spot 110 without the diffractive structure and the spot 111 with the diffractive structure attached to the servo-lens 40. As can be seen from Fig. 7 compared to Fig. 6, the spot size is reduced as compared to the situation without the diffracting structure 100 (in these figures, the black squares 112 indicate the size of the standard four-quadrant detector used in optical pick-up devices). At least more than 10% of the light of said second beam falling outside the detector when the grating according to the invention is not present is not refocused onto the detector when the grating is present. More preferably, more than 25% is refocused onto the detector. The normalized tilt error-signal is derived from the position of the spot from the second light source on said four-quadrant detector. If A, B, C and D refer to the individual quadrants, the normalized radial-tilt error signal, called RTES, is given by:

$$RTES = \frac{A+B-C-D}{A+B+C+D} \qquad (3)$$

The simulated normalized radial-tilt error-signal obtained is shown in Fig. 8.

In the second case, as shown in Fig. 12B, the diffractive structure 100 may be attached to the objective lens 27. The radius and the corresponding pitch for each ring are then given in the

following table 2, together with the numerical aperture (NA) belonging to the radius:

Table 2

Ring number	Radius (mm)	Pitch (μm)	NA
1	1.360	0.0	0.49
2	1.624	264.0	0.59
3	1.799	175.0	0.65

In order not to influence the returning light from the second light source when accessing a second type disc having said second cover layer, the diffractive structure is confined to the region defined by $0.5 < NA < 0.65$, where it acts as a weak positive lens for the light emitted by the second light source. Due to the lens effect, the rays are re-focused on the servo-detector (it may be noted that the diffractive structure has an overall aspheric shape in order to fit onto the aspheric surface of the objective lens). As described above, the grating structure may be approximated by a phase-step profile, so that the light from the first light source is not affected when passing through the region $0.5 < NA < 0.65$. The normalized radial-tilt error-signal obtained with this modified objective lens is shown in Fig. 9.

The actual focus position of the edge rays (i.e., the part of the light from the second light source that falls in the

region 0.5 < NA < 0.65 on its way to the disc) is important. This is shown in Figs. 10 and 11, where Fig. 10 shows the light from the second light source that passes through the objective lens (OL) 27 and is focused onto the information layer 120 of the disc 1 (note that Fig. 10 shows an unfolded light path, i.e., the system is shown in transmission, while Fig. 11 is a magnified view of the region around the information layer 120). As can be seen, the actual focus 121 is positioned "behind" the information layer 120. It is important that the diffractive structure brings the edge rays 122 to a focus 123 in front of this point and only slightly behind the information layer 120. Focusing the edge rays onto the information layer suppresses the beam landing as a consequence of disc tilt and hence does not lead to a useful error-signal.

In the third case, as shown in Fig. 2, the diffractive structure 100 is mounted on a plate 102 which is positioned between the servo-lens 40 and the servo-detector 42.

It must be understood that the invention thus defined is not limited to the above-mentioned implementations. While in the above described embodiment, the first wavelength is smaller than the second wavelength, it is possible that the first wavelength may also be larger than the second wavelength. Also, while in the above-described embodiment, explicit reference is made to a detector with four quadrants, it appears that the principle can be applied to a detector having at least two or even six and more segments. Although the embodiment described above indicates a

situation where the beam from the second light source used for the tilt measurement is confined to a numerical aperture which is smaller than the numerical aperture of the beam from the first light source, it is appreciated that a similar principle to the one given above can be applied to the opposite situation.